RESEARCH PAPER

Secular Trends in Birthweights in Two Epochs Over 40 Years in a Tertiary Care Center

DEENA THOMAS, PRATIMA ANAND, ANU THUKRAL, RAMESH AGARWAL, ASHOK DEORARI, M JEEVA SANKAR

From Division of Neonatology, Department of Pediatrics, All India Institute of Medical Sciences, New Delhi.

Correspondence to: Dr M Jeeva Sankar, Additional Professor, WHO Collaborating Centre for Training and Research in Newborn Care, Department of Pediatrics, All India Institute of Medical Sciences, New Delhi. jeevasankar@gmail.com

Received: December 07, 2021; Initial review: January 05, 2022; Accepted: May 24, 2022.

Objective: To compare the average birthweights and the weight centiles of the 'new' growth charts with the 'old' (1974) charts developed in the same unit four decades ago.

Methods: Birthweight and gestation data of the eligible 12,355 singleton neonates born between 2009 and 2016 at a level-3 neonatal unit at a public sector hospital were used to develop the new growth chart. We then compared the prevalence of small for gestational age (SGA) and large for gestational age (LGA) classified by the new charts and the old charts, the incidence of short-term adverse outcomes among them, and the diagnostic performance of both the charts to identify the adverse outcomes in a separate validation cohort.

Results: The mean birthweights of boys and girls across all gestations were higher by 150-200 g and 100-150 g, respectively, in the new chart. The prevalence of SGA doubled (9.8% vs 4.7%), but LGA decreased by one-third (17.5% vs 25.9%) with the new chart. However, the proportion of SGA and LGA having one or more short-term adverse outcomes, and the diagnostic performance of both the charts to identify neonates with short-term adverse outcomes, were comparable.

Conclusion: There was an upward shift in the birthweights by about 150 g across all gestations in the new chart compared to the old chart developed 40 years ago. The findings imply the need to consider using updated growth charts to ensure accurate classification of size at birth of neonates.

Keywords: *Gestational age, Growth chart, Newborn, Small for gestational age*.

Published online*:** May 31, 2022; ***PII: S097475591600428

Advances in perinatal and neonatal care in the last few decades have led to significant improvement in the survival of extreme preterm and low birthweight neonates across the globe. Concurrently, there has been an increase in the average birthweight of neonates over the years in many countries [1-3]. With the change in birthweights, the growth centiles and the proportion of small-for-gestational age (SGA) neonates are also expected to change; though, the magnitude of the change may vary across regions [2].

We planned to examine the average birthweights and the birthweight centiles (from 3rd centile to 97th centile) on two charts – generated almost 40 years apart from the same unit. We compared the cut-offs at different centiles and the prevalence of SGA and large-for-gestational age (LGA) neonates with the 'new' and 'old' charts. We also evaluated the charts' diagnostic performance to identify SGA and LGA neonates at risk of short-term adverse outcomes.

METHODS

In this study conducted at the level-3 neonatal unit of our public sector referral hospital, we enrolled two cohorts of neonates – one comprising the eligible neonates born between March, 2009 and November, 2016 for the generation of the new growth charts and the other including the neonates born between December, 2016 and August, 2017 for validation of the new chart and comparison with the old chart produced in 1974 [4]. The institute ethics committee approved the study protocol.

Invited Commentary: Pages 601-02.

For developing the new centiles, we obtained the relevant information from the unit's electronic database system for all the neonates born between 2009 and 2016. All consecutive live births during this period were eligible for inclusion in the study. We excluded neonates born to mothers with significant medical and obstetric morbidities known to affect fetal growth, including type 1 and type 2 diabetes mellitus, chronic hypertension, heart disease, renal disease, seizure, tuberculosis during pregnancy, malaria, asthma, hepatitis, syphilis, HIV infection, severe anemia (hemoglobin <7 g/dL), gestational hypertension, preeclampsia/eclampsia, and gestational diabetes mellitus. Twins or higher-order births and neonates with major

congenital malformations or immune or non-immune hydrops were also excluded.

Gestation at birth is determined in the unit from the mother's last menstrual period (LMP). If there is a discrepancy of more than seven days between the LMP and the first-trimester ultrasound (USG) dating, the gestational age is revised as per the USG dating [5]. In pregnancies with unsure dates and non-availability of first-trimester ultrasound dating, the expanded new Ballard score is used to determine the gestational age. Birthweight is documented within one hour of birth using an electronic weighing scale with 5 g calibration (ADE M10400). The designated staff of the neonatal intensive care unit calibrates the weighing machines in all the birthing areas once weekly using pre-specified weights.

Developing the new chart: The birthweight and gestational age data were entered separately in R software (ver 3.6.1) for boys and girls. Smoothening was done using the Lambda-Mu-Sigma (LMS) method [6]. After smoothe-ning, the new gender-specific charts containing the 3rd, 10th, 50th, 90th, and 97th centiles were obtained.

Extracting data from the old AIIMS growth chart: The 'old' regional growth chart – generated by Singh, et al. [4] – used the data of all consecutive singleton neonates born at the hospital between 1971 and 1973, irrespective of the maternal morbidities and neonatal conditions (*n*=3550). Neonates with uncertain gestation at birth (because of the disparity between the calculated and clinically assessed gestational age) and with no birthweight records were excluded. Birthweight at different centiles at each gestational age was derived from the 'old' growth chart using the WebPlotDigitizer developed by Rohtagi, et al. [7] (available at *https://automeris.io/WebPlotDigitizer/*).

Neonates born at 31 to 41 weeks between December, 2016 and August, 2017 (validation cohort) were used to compare the *i*) prevalence of SGA and LGA; *ii*) incidence of short-term adverse outcomes, including in-hospital morta-lity or one of 14 predefined key morbidities among SGA and LGA neonates identified by both the old and new charts; and, *iii*) diagnostic performance to detect the short-term adverse outcomes among SGA and LGA neonates. Neo-nates in the validation cohort were prospectively tracked from birth till 28 days of life – for another study (Under publication) – to detect the occurrence of one or more adverse outcomes. The following adverse outcomes, apart from neonatal mortality, were prospectively recorded in the validation cohort of neonates: need for delivery room resuscitation (BE <12 or positive pressure ventilation >30 sec), seizures (clinical), respiratory support for more than 24 hours or NICU stay for more than 48 hours, sympto-matic hypoglycemia, culture-positive or clinical sepsis, symptomatic hypocalcemia, polycythemia requiring intra-venous fluids/partial exchange transfusion, any acute life-threatening event, persistent pulmonary hypertension (PPHN) confirmed by echocardiography, bronchopul-monary dysplasia (BPD), retinopathy of prematurity (ROP) requiring laser therapy, patent ductus arteriosus requiring treatment, shock requiring inotropes, and necrotizing enterocolitis.

Statistical analysis: This was done using STATA version 15.1 (StataCorp). The diagnostic performance of both charts was determined using the '*diagt'* command in Stata. The relative risk of adverse outcomes among the additional SGA identified by the new chart and the LGA missed was computed using the '*csi'* command in Stata.

RESULTS

Of the 18,979 neonates born between March, 2009 and November, 2016, four with implausible birthweights and gestation (wrong data entry), 31 born before 24 weeks or after 41 weeks, and six neonates with ambiguous genitalia were excluded; another 6583 were excluded based on the pre-specified exclusion criteria. Gender-specific growth charts were then constructed using the data of 6583 boys and 5772 girls (**Fig. 1** and **2**). The mean birthweight and gestational age of the boys and girls were 2841 g and 37.6 weeks, and 2740 g and 37.7 weeks, respectively. About one-fourth were low birthweight, and nearly one-fifth were preterm (**Web Table I**). **Web Table II** provides the birthweights of boys and girls at the 10th, 50th, and 90th centiles. The mean birthweight of boys and girls with the new chart was nearly 150-200 g and 100-150 g more than the old chart across almost all gestational categories, respectively (except 30-31weeks in boys and 30-31 and 32-33 weeks in girls) (**Table I**).

The validation cohort included 1294 neonates born between December, 2016 and August, 2017. The proportion of neonates labeled SGA was almost twice with the new charts (9.8% vs 4.7%). In contrast, the proportion of neonates marked as LGA decreased by nearly one-third – from 25.9% with the old chart to 17.5% with the new chart (**Fig. 3**). The prevalence of AGA increased by 3.3% (72.7% vs 69.4%). The proportion of SGA and LGA having one or more short-term adverse outcomes is comparable between the charts (**Table II**).

Both the new and old charts had similar sensitivity (29% vs 30%), specificity (73% vs 69%), positive predictive value (32% vs 30%), negative predictive value (71% vs 70%), and diagnostic odds ratio (1.13 vs 0.98) for identifying short-term adverse outcomes among SGA or LGA neonates (**Web Table III**).

To determine if the observed increase of 100-200 g in

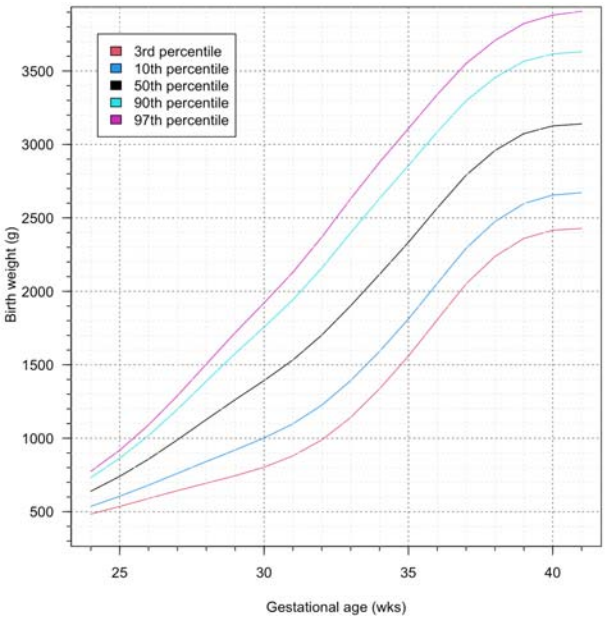

Fig. 1 New AIIMS neonatal growth chart– Boys.

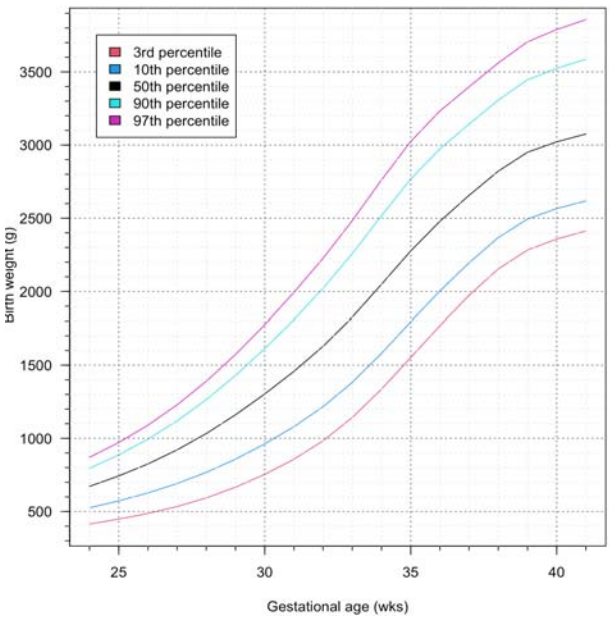

Fig. 2 New AIIMS neonatal growth chart– Girls.

mean birthweights with the new chart was purely due to the exclusion of neonates with higher-order gestation and congenital malformations and those who were born to mothers with chronic morbidities, we conducted a sensitivity analysis by including all the neonates born between March, 2009 and November, 2016, irrespective of the maternal and neonatal morbidities. Of the total 18,979 neonates, four with implausible birth weights and

Table I Birthweight at Different Gestation With the 'new' and 'old' AIIMS Neonatal Growth Charts

Gestational age (wk)	*Old chart*		*New chart*		*Mean difference*
	n	*Birthweight (g)*	*n*	*Birthweight (g)*	*(95% CI)*
Boys					
30-31	10	1580 (820)	60	1442 (306)	-138 (-419 to 143)
32-33	19	1660 (350)	127	1785 (426)	125 (-78 to 328)
34	31	1940 (280)	134	2142 (405)	202 (50 to 354)
35	24	2110 (340)	222	2324 (384)	214 (53 to 375)
36	58	2360 (410)	507	2553 (430)	193 (81 to 305)
37	114	2630 (400)	1498	2803 (389)	173 (98 to 247)
38	259	2790 (410)	1886	2957 (392)	167 (116 to 218)
39	337	2960 (410)	1400	3083 (385)	123 (76 to 169)
40	689	2960 (400)	638	3132 (386)	172 (130 to 214)
41	167	3060 (450)	38	3106 (422)	46 (-112 to 204)
Girls					
30-31	11	1470 (240)	57	1416 (291)	-54 (-241 to 133)
32-33	18	1740 (260)	90	1699 (364)	-41 (-220 to 138)
34	13	1950 (370)	119	2014 (384)	64 (-157 to 285)
35	18	2280 (510)	205	2314 (397)	34 (-163 to 231)
36	60	2340 (480)	427	2481 (394)	141 (31 to 251)
37	70	2540 (430)	1189	2663 (379)	123 (31 to 215)
38	251	2680 (390)	1605	2831 (362)	151 (102 to 199)
39	305	2830 (390)	1271	2968 (389)	138 (89 to 197)
40	680	2900 (400)	699	3028 (367)	128 (87 to 168)
41	195	3030 (400)	47	3107 (439)	77 (-53 to 207)

Values in mean (SD). AIIMS - All India Institute of Medical Sciences.

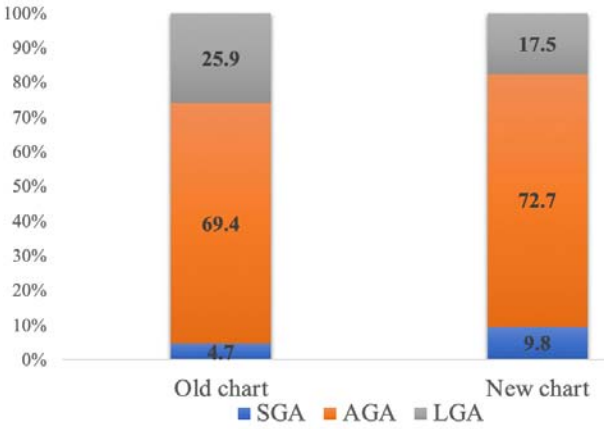

Fig. 3 Proportion of SGA, AGA, and LGA in the validation cohort using both charts.

gestation (wrong data entry), 31 born before 24 weeks or after 41 weeks, and six neonates with ambiguous genitalia were excluded. The mean birthweights and 10th, 50th, and 90th percentile of the remaining 18,938 neonates (10,073 boys) were compared to the old chart **(Web Table IV** and **V)**. Mean birthweights were nearly 100 g more even when all neonates were included.

DISCUSSION

We compared growth charts developed in 1974 and 2016 at our center, and found an upward shift in the average birth weight by about 150-200 g in boys and 100-150 g in girls at almost all the gestations over the last 40 years. Even with the inclusion of neonates born to mothers with chronic morbidities, the mean weights across all gestational categories were nearly 100 g in the new chart signifying a change over the years.

The secular trend in birthweights over four decades is probably because of the improvements in antenatal and perinatal care, and the nutritional and socioeconomic status of the population in general. However, similar secular trends of improved birthweights were not apparent in cohorts that were 15 to 20 years apart from the same institutes (viz., Safdarjung hospital [8,9], AIIMS [4,10] and CMC, Vellore [11,12]). The shorter interval between the cohorts could possibly explain the lack of trends of improved birthweights in these studies. Amongst the International charts, the updated Babson and Benda charts over 27 years (1976 to 2003) showed a statistically significant difference in weights only for neonates with term gestation [13,14].

The upward shift of the mean birthweights could explain the increase in SGA prevalence and reduction in LGA prevalence. The proportion of SGA with adverse outcomes was lower in the new chart, but the chart's performance in identifying short-term adverse outcomes among SGA or LGA neonates was comparable to that of the old chart. Moreover, the prevalence of AGA increased by 3.3% (72.7% vs 69.4%), which implies that for every 1000 neonates born in any unit, 33 fewer need to be screened for hypoglycemia/polycythemia in the immediate neonatal period.

Table II Short-Term Adverse Outcomes in Validation Cohort Using Two Growth Charts

Growth category	*Babies with adverse outcomes*	
	Old chart	*New chart*
Small-for-gestational age (SGA)	25 (40.9)	47 (37.0)
Appropriate-for-gestational age (AGA)	271 (30.2)	276 (29.3)
Large-for-gestational age (LGA)	93 (27.7)	66 (29.2)

Values in no. (%). The number of SGA, AGA and LGA babies in the old chart was 61, 898 and 335; and 127, 941 and 226 in the new chart, respectively.

Compared to 8% of preterm neonates in the 1974 AIIMS chart, the preterm neonates formed 16.6% of the cohort in the new chart, which is considerably higher than the previous regional charts by Ghosh, et al. (13%) [8] and Fenton charts (1.9%). With the improving survival rates of extreme low birth weight and extreme preterm neonates, these neonates must form a considerable proportion of the cohort used to develop the neonatal charts. Given that the new charts are created using a much larger sample size and provide gender-specific charts, it is preferable to use the new charts for accurate classi-fication of neonates at birth. The WHO MGRS growth charts are the preferred choice for monitoring the growth of term neonates [15]. However, the lack of gestation-wise data in those charts, even among term neonates, makes it challenging to classify neonates as AGA/SGA/LGA at different gestations, thereby preventing them from being used as the optimal 'size-at-birth' charts.

The strengths of the current study included large sample size, application of the LMS smoothening technique, and selective inclusion of mothers without health constraints. We used a cohort of neonates who were prospectively observed for predefined short-term adverse outcomes to validate the new chart. The study is limited by the retrospective nature of the collected data and the consequent lack of rigorous methodology followed in the construction of prescriptive charts like Intergrowth 21st [16], wherein the healthy mothers were longitudinally followed up to allow for accurate assessment of fetal growth and subsequent growth of neonates. Moreover, there was restricted recruitment of extreme preterm neonates, though the proportion is comparable with the global standard charts. The disparity in inclusion criteria of

WHAT IS ALREADY KNOWN?

- With improving antenatal and perinatal care, neonatal birthweight centiles are expected to change with time.

WHAT THIS STUDY ADDS?

- There is an upward shift in the mean birthweights by 150-200 g among boys and 100-150 g among girls across all the gestational categories compared to the regional chart developed 40 years ago.

mothers in the two charts may have implications on the interpretation of the comparative analysis. Inclusion of neonates from a single center that deals predominantly with high-risk pregnancies is also likely to affect the generalizability of the study results.

Comparing two epochs over the last 40 years shows an upward shift in the birth weights across the gestation by about 150-200 g and 100-150 g among boys and girls, respectively. The proportion of neonates classified as SGA and AGA was also higher, and the performance to identify neonates with short-term adverse outcomes was comparable to the old centiles. The findings imply the need to consider using updated growth charts to ensure accurate classification of size at birth.

Ethics clearance: IEC, AIIMS, New Delhi; No. IECPG/768/30.01.2020 dated Feb 11, 2020.
Note: Additional material related to this study is available with the online version at *www.indianpediatrics.net*
Contributors: DT: designed the study, collected the data, did the initial analyses, and drafted the initial manuscript; PA: contributed to the initial data collection & analysis and helped draft the initial manuscript; RA, AT, AD: provided critical insights into the study design, supervised the conduct of the study and critically reviewed the final manuscript; MJS: helped design the study, supervised the conduct of the study, did the final analysis, and reviewed and finalized the manuscript. All authors approved the final manuscript.
Funding: None; *Competing interests*: None stated.

REFERENCES

1. Oken E. Secular trends in birthweight. Nestle Nutr Inst Workshop Ser. 2013;71:103-14.
2. Margerison-Zilko C. The contribution of maternal birth cohort to term small for gestational age in the United States 1989-2010: An age, period, and cohort analysis. Paediatr Perinat Epidemiol. 2014;28:312-21.
3. Aris IM, Kleinman KP, Belfort MB, et al. A 2017 US reference for singleton birth weight percentiles using obstetric estimates of gestation. Pediatrics. 2019;144: e20190076.
4. Singh M, Giri SK, Ramachandran K. Intrauterine growth curves of live-born infants. Indian Pediatr. 1974;11:475-79.
5. Committee Opinion No 700: Methods for estimating the due date. Obstet Gynecol. 2017;129:e150-e154.
6. Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalized likelihood. Stat Med. 1992;11: 1305-19.
7. Rohatgi A. Web Plot Digitizer; 2015. Accessed September 10, 2020. Available from: *http://www.arohatgi.info/WebPlot Digitizer*
8. Ghosh S, Bhargava SK, Madhavan S, et al. Intra-uterine growth of north Indian babies. Pediatrics. 1971;47:826-30.
9. Mohan M, Prasad SR, Chellani HK, Kapani V. Intrauterine growth curves in north Indian babies: weight, length, head circumference and ponderal index. Indian Pediatr. 1990; 27:43-51.
10. Singhal PK, Paul VK, Deorari AK, et al. Changing trends in intrauterine growth curves. Indian Pediatr. 1991;28:281-3.
11. Kumar VS, Jeyaseelan L, Sebastian T, et al. New birth weight reference standards customised to birth order and sex of babies from south India. BMC Pregnancy Childbirth. 2013; 13:38.
12. Mathai M, Jacob S, Karthikeyan NG. Birthweight standards for south Indian babies. Indian Pediatr. 1996;33:203-9.
13. Babson SG, Benda GI. Growth graphs for the clinical assessment of infants of varying gestational age. J Pediatr. 1976; 89:814-20.
14. Fenton TR. A new growth chart for preterm babies: Babson and Benda's chart updated with recent data and a new format. BMC Pediatr. 2003;3:13.
15. WHO Multicentre Growth Reference Study Group. Assessment of differences in linear growth among populations in the WHO Multicentre Growth Reference Study. Acta Paediatr Suppl. 2006;450:56-65.
16. Villar J, Cheikh Ismail L, Victora CG, et al. International standards for newborn weight, length, and head circumference by gestational age and sex: The Newborn cross-sectional study of the INTERGROWTH-21st project. Lancet. 2014;384:857-68.

Web Table I. Baseline characteristics

Characteristic	*Males n=6583*	*Females n=5772*
Birth weight (g)*	2841 ± 527	2740 ± 507
Low birth weight	1394 (21.2%)	1570 (27.2%)
Very low birth weight	152 (2.3%)	145 (2.5%)
Extremely low birth weight	36 (0.5%)	42 (0.7%)
Gestation (weeks)*	37.6 ± 1.9	37.7 ± 2
Late preterm	863 (13.1%)	751 (13%)
Moderate preterm	127 (1.9%)	90 (1.6%)
Very/extreme preterm	133 (2.0%)	120 (2.1%)

*Data expressed as n (%) *Data expressed as mean ± SD.*

Web Table II. The 10th, 50th and 90th percentile of male and female neonates in the 'new' chart at various gestation

GA* (weeks)	n		10th percentile (grams)		50th percentile (grams)		90th percentile (grams)	
	Male	Female	Male	Female	Male	Female	Male	Female
24	3	3	628	685	640	717	696	764
25	6	3	591	691	705	750	824	786
26	7	8	698	612	817	767	976	889
27	10	16	871	669	987	948	1207	1130
28	24	12	754	693	1151	894	1342	1217
29	23	21	1087	880	1305	1180	1687	1473
30	22	26	1067	1037	1352	1337	1604	1578
31	38	31	1045	1187	1521	1430	1859	1812
32	59	41	1191	1080	1673	1582	2049	1959
33	68	49	1285	1475	1891	1827	2491	2124
34	134	119	1586	1484	2191	2059	2636	2418
35	222	205	1841	1792	2324	2319	2812	2848
36	507	427	1948	1997	2554	2474	3108	2984
37	1498	1189	2317	2214	2803	2642	3280	3161
38	1886	1605	2466	2375	2958	2824	3434	3277
39	1400	1271	2603	2489	3072	2956	3580	3461
40	638	699	2648	2584	3114	3002	3608	3511
41	38	47	2559	2535	3117	3096	3653	3550

**GA: gestational age*

Web Table III. Diagnostic performance of 'new' vs. 'old' AIIMS chart for identifying GA/ LGA with short term adverse outcomes

Parameter	*'New' chart*	*'Old' chart*
Sensitivity	29.0% (24.6-33.8)	30.1% (27.6-32.6)
Specificity	73.5% (70.5-=76.3)	69.3% (66.2-72.3)
Positive predictive value	32.0% (27.2-37.2)	29.8% (25.3-34.6)
Negative predictive value	70.7% (67.6-73.6)	69.8% (66.7-72.8)
Positive likelihood ratio	1.10 (0.91-1.32)	0.98 (0.76-1.27)
Negative likelihood ratio	0.97 (0.90-1.04)	1.01 (0.93-1.09)
Diagnostic odds ratio	1.13 (0.87- 1.48)	0.98 (0.76-1.2)

95% confidence intervals provided in parentheses
SGA: Small for gestational age; LGA: Large for gestational age

Web Table IV. Comparison of mean birth weights and 10th, 50th and 90th percentile of 'new' chart with eligible neonates vs. all neonates (males)

GA (wks)	n		Mean weight (g)		10th percentile (g)		50th percentile (g)		90th percentile (g)	
	Eligible neonates	All neonates	Eligible neonates	All neonates	Eligible neonates	All neonates	Eligible neonates	All neonates	Eligible neonates	All neonates
30	22	69	1345	1336	1067	986	1352	1335	1604	1636
32	59	158	1656	1626	1191	1150	1673	1640	2049	2089
34	134	302	2142	2078	1586	1490	2191	2068	2636	2627
37	1498	2374	2803	2791	2317	2261	2803	2788	3280	3323
40	638	824	3132	3109	2648	2602	3114	3106	3608	3593
24-41 weeks	6583	10073	2841	2748						

Eligible neonates *are the neonates used to construct the 'new' male growth chart after exclusion of maternal and neonatal morbidities;* ***All neonates*** *are all the male neonates during the study period*

Web Table V. Comparison of mean birth weights and 10th, 50th and 90th percentile of 'new' chart with eligible neonates vs. all neonates (females)

GA (wks)	n		Mean weight (g)		10th percentile (g)		50th percentile (g)		90th percentile (g)	
	Eligible neonates	All neonates	Eligible neonates	All neonates	Eligible neonates	All neonates	Eligible neonates	All neonates	Eligible neonates	All neonates
30	26	74	1317	1254	1037	804	1337	1250	1578	1622
32	41	109	1544	1507	1080	1078	1582	1539	1959	1876
34	119	282	2014	1944	1484	1420	2059	1934	2418	2411
37	1189	1947	2663	2659	2214	2167	2642	2642	3161	3193
40	699	853	3028	3017	2584	2562	3002	3000	3511	3505
24-41 weeks	5772	8865	2740	2644						

Eligible neonates *are the neonates used to construct the 'new' female growth chart after exclusion of maternal and neonatal morbidities;* ***All neonates*** *are all the female neonates during the study period*